Project Title: Kinetic Parameters for the Exchange of Hydrate Formers

Award Number: 65213

Submitting Official: Mark D. White, Research Engineer, PNNL

Project Period: Begin: 07/01/2013 End: open

Reporting Period: Begin: 07/01/2014 End: 09/30/2014

Report Term: Quarterly

Executive Summary

Through the funding support of the U.S. Department of Energy under this Field Work Proposal the Pacific Northwest National Laboratory (PNNL) will investigate numerically and experimentally an unconventional technology for producing geologic accumulations of natural gas hydrates. The guest-molecule-exchange technology involves replacing methane molecules with the clathrate structure with alternative guest molecules, such as carbon dioxide and nitrogen. The alternative guest molecules are selected to maintain the original hydrate structure and be thermodynamically preferred under the reservoir temperature and pressure conditions. The numerical component of the proposed work will investigate the Iġnik Sikumi Gas Hydrate Field Trial, a collaborative project conducted by the U.S. DOE National Energy Technology Laboratory, ConocoPhillips, and the Japan Oil, Gas, and Metals National Corporation on the Alaska North Slope. The experimental component of the proposed research will provide supporting kinetic exchange data, needed by the numerical simulations. Both the numerical and experimental elements are preliminary investigations due to the limited scope of the proposed work.

Goals and Objectives

This project will investigate the kinetics associated with the production natural gas from hydrate bearing geologic media via unconventional technologies. The principal production technology of concern for this research will be that of exchanging CO_2 and N_2 with clathrated CH_4. The so called guest-molecule exchange technology is an attractive technology from the perspective of its potential for maintain the geomechanical integrity of the reservoir formation, in addition to its carbon neutral potential. As with other unconventional technologies its realization to produce natural gas will depend on an understanding of the processes and our ability to exploit this understanding. The approach in this project will be to understand the kinetic mechanisms that control the exchange of hydrate formers using numerical simulation to interpret field-scale trials, laboratory experiments to

determine kinetic parameters, and code comparison to verify mathematical models and solution schemes.

Budget Period 1

During the first budget period, this project will investigate the kinetics of exchanging CO_2 and N_2 with clathrated CH_4 in hydrate bearing geologic media. The project comprises two distinct components: 1) numerical investigation of the 2012 Iġnik Sikumi gas hydrate field trial, and 2) experimental investigation of kinetic exchange processes in laboratory-scale hydrate bearing unconsolidated sands. The principal objective of the numerical component will be to provide an interpretation of the data gathered at Iġnik Sikumi Well #1. The experiment component of this project is designed to provide kinetic exchange parameters needed in the numerical simulation. The principal objective of the two experiments is to provide an order of magnitude value to the kinetic exchange parameters for the field-scale simulations of the Iġnik Sikumi gas hydrate field trial.

Budget Period 2

During the second budget period, this project will continue and expand the investigations of the first budget period. Numerical simulations of the 2012 Iġnik Sikumi gas hydrate field trial will continue to resolve disagreements between simulation results and field trial observations, and to provide a more thorough interpretation of the field results. Laboratory experiments designed to provided kinetic parameters under controlled conditions will continue, and a code comparison study will start that will be directed at expanding the International Hydrate Code Comparison Study to problems involving gas hydrates of mixtures of CH_4, CO_2, and N_2 hydrate formers. A suite of problems for the code comparison study are currently being prepared by West Virginia University, which involve hydrates of pure components and component mixtures of CH_4, CO_2, and N_2. The laboratory experiments and code comparison study are currently unfunded.

Technical Highlights, Results and Discussion

This project is divided into budget periods and tasks.

Budget Period 1

Iġnik Sikumi History Match

The paper for the 2014 Offshore Technology Conference, entitled “Guest Molecule Exchange Kinetics for the 2012 Iġnik Sikumi Gas Hydrate Field Trial,” was completed and submitted. Contributions to the paper for the International Conference on Gas Hydrates (ICGH8-2014) to be held in Beijing, China, 28 July – 1 August, 2014, entitled “Review of the findings of the Ignik Sikumi CO_2-CH_4 gas

hydrate exchange field trial," was submitted to Brian Anderson at West Virginia University. Both of these papers document the simulations conducted under this project with the STOMP-HYDT-KE simulator on the Ignik Sikumi #1 Field Trial.

CH_4-CO_2-N_2 Exchange Study

There is no progress to report.

Pressurized X-Ray Diffraction Study

There is no progress to report.

Budget Period 2

Iġnik Sikumi History Match

This task received funding and work on the task will be initiated during the first quarter of FY2015.

Code Comparison Study (Currently Unfunded)

This task is currently unfunded.

CH_4-CO_2-N_2 Exchange Study (Currently Unfunded)

This task is currently unfunded.

Pressurized X-Ray Diffraction Study (Currently Unfunded)

This task is currently unfunded.

Risk Analysis

The risks associated with this project are those described in the Project Management Plan.

Schedule/Milestone Status

Budget Period 1

Iġnik Sikumi History Match

Title: Review Archived Data

This milestone was completed in preparing for the numerical simulations of the Ignik Sikumi #1 Field Trial. This work is documented in the OTC 2014 paper (White and Lee, 2014).

Title: Simulate Ignik Sikumi Field Trial

This milestone was completed in conducting the numerical simulations of the Ignik Sikumi #1 Field Trial. This work is documented in the OTC 2014 paper (White and Lee, 2014).

Title: Compare Simulation Results

This milestone was completed in writing the contribution to the ICGH8-2014 paper with Brian Anderson (Anderson et al., 2014).

Title: Report Interpretations

This milestone was completed by writing two papers documenting the comparison of the STOMP-HYDT-KE simulations against the field observations from the Ignik Sikumi #1 Field Trial (White and Lee, 2014; Anderson et al., 2014).

Budget Period 2

Title: Submit a Manuscript to a Peer-Reviewed Journal

This milestone is uncompleted.

Cost Status

This quarter concluded with a cost variance of about $36.4k, principally due to the non-start of the experimental tasks. The cost status spreadsheet is shown on the following page.

Conclusion

The start of this project was delayed to allow for completion of other FY14 projects, giving researchers a block of time to start the project.

References

White, M.D. and W.S. Lee. 2014. “Guest molecule exchange kinetics for the 2012 Ignik Sikumi Gas Hydrate Field Trial,” *Proceedings of the Offshore Technology Conference held in Houston, Texas, USA, 5-8 May 2014, OTC-25374-MS*.

Anderson, B., R. Boswell, T. S. Collett, H. Farrell, S. Ohtsuka, and M. White. 2014. "Review of the findings of the Ignik Sikumi CO_2-CH_4 gas hydrate exchange field trial," *Proceedings of the 8th International Conference on Gas Hydrates (ICGH8-2014), Beijing, China, 28 July - 1 August, 2014*.

Baseline Reporting Quarter		FY2013	FY2014				FY2015			
		Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Baseline Cost Plan										
Federal Share	Task 1.0	$1,250	$1,250	$1,250	$1,250					
	Task 2.0	$11,250	$11,250	$11,250	$11,250					
	Task 3.0	$10,000	$10,000	$0	$0					
	Task 4.0	$10,000	$10,000	$0	$0					
	Task 5.0						$1,250	$1,250	$2,500	
	Task 6.0						$25,000	$25,000	$25,000	
Non-Federal Share										
Total Planned Cost (Federal and Non-Federal)		$32,500	$32,500	$12,500	$12,500	$0	$26,250	$26,250	$27,500	
Cumulative Planned Cost		$32,500	$65,000	$77,500	$90,000	$90,000	$116,250	$142,500	$170,000	
Actual Incurred Costs										
Federal Share	Task 1.0	$0	$0	$0	$0	($345)				
	Task 2.0	$0	$21,876	$19,014	$10,139	$0				
	Task 3.0	$0	$418	$2,507	$0	($20)				
	Task 4.0	$0	$0	$0	$0	$0				
	Task 5.0									
	Task 6.0									
Non-Federal Share										
Total Actual Cost (Federal and Non-Federal)		$0	$22,294	$21,521	$10,139	($365)				
Cumulative Actual Cost		$0	$22,294	$43,815	$53,954	$53,589				
Variance										
Federal Share	Task 1.0	$1,250	$1,250	$1,250	$1,250	$345				
	Task 2.0	$11,250	($10,626)	($7,764)	$1,111	$0				
	Task 3.0	$1,250	$832	($1,257)	$1,250	$20				
	Task 4.0	$11,250	$11,250	$11,250	$11,250	$0				
	Task 5.0									
	Task 6.0									
Non-Federal Share		$0	$0	$0	$0	$0	$0	$0	$0	
Total Cost Variance (Federal and Non-Federal)		$32,500	$10,206	($9,021)	$2,361	$365	$26,250	$26,250	$27,500	
		$0	$0	$0	$0	$0	$0	$0	$0	
Cumulative Cost Variance		$32,500	$42,706	$33,685	$36,046	$36,411	$116,250	$142,500	$170,000	

Task	Milestone Description	FY13	FY2014				FY2015				Planned Start Date	Planned End Date	Actual Start Date	Actual End Date
		Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4				
Task 2	Review archived data										7/1/13	9/30/13	10/28/13	11/30/13
Task 2	Simulate Ignik Sikumi field trial										10/1/13	12/31/13	12/1/13	3/31/14
Task 2	Compare simulation results										1/1/14	3/31/14	1/1/14	4/8/14
Task 2	Report interpretations										4/1/14	6/30/14	4/1/14	6/30/14
Task 3	Conduct Kinetic Exchange Exp.										10/1/13	12/31/13	1/1/14	
Task 4	Conduct Hydrate Structure Exp.										10/1/13	12/31/13	1/1/14	
Task 6	Publish Manuscript										10/1/14	6/30/15	10/1/14	